Workshop Summary: Instruments & Observations

Christoph U. Keller
(as John W. Harvey)

National Solar Observatory
Contents

- Background: SEC Roadmap and HRSOT
- Science questions and required observations
- Photon flux considerations
- Opportunities for space mission
- Strawman mission
SEC Roadmap: The Background
High-Resolution Solar Optical Telescope

**Fundamental Question:**
- What are the dynamics of the flux tubes that drive atmospheric heating?

**Science Objectives:**
- Understand the internal structure, heating, and evolution of the Sun’s magnetic flux tubes
- Understand the relationships between fine-scale photospheric magnetic activity and overlying regions
- Understand the changes in magnetic energy, structure, and helicity in active region magnetic fields

**Mission Description:**
- Sun-synchronous, Earth-orbiting satellite

**Measurement Strategy:**
- Very-high-angular-resolution observations of intensity, velocity, and vector magnetic field
- EUV images of chromospheric and coronal structures

**Technology Requirements**
- High-data-rate communication
- Large-aperture optics and/or interferometers
Science Questions

- “Do we have a powerplug?“
- Structure and nature of seismic events
- Nature and properties of local dynamo, true flux spectrum
- Property distributions of small-scale magnetic elements
- Evolution of active regions (“The only way to see AR emergence … you have to look for something else.“)
- Evolution of magnetic helicity
- Subphotospheric structure of sunspots and plages
- Nature of magnetoconvection in sunspots
- Everything about s…
- Structure and dynamics of transition region
- Connection of magnetic fields and energy channeling from photosphere to corona
- Processes heating the upper atmosphere
- Properties of coronal magnetic field ("trying to do the impossible“)
- What makes coronal fields unstable?
“I want people and money”
- Higher spatial and temporal resolution than presently possible
- Higher polarimetric accuracy
- Field of view up to 8 arcmin
- Many lines simultaneously
- Spatial resolution of 10 km or better
- Temporal resolution of a second
- Transition Region spectrograph with high spatial resolution
- IR imaging spectropolarimetry 1-1.5 µm
- ATST in space
April 5, 2001

Beyond Solar-B Workshop Summary:
Instruments and Observations
Present Capabilities

magnetogram

arcsec

relative frequency

filling factor

0 0.05 0.1 0.15

0 0.4 0.6 0.8 1
Beyond Solar-B Workshop Summary: Instruments and Observations

April 5, 2001

Solar Science and Missions Overview

- Interior structure and dynamics
- Origin of solar activity cycle, dynamo
- Origin of solar variability
- Transient eruptions, flares, and coronal mass ejections
- Heating of chromosphere and corona, origin of solar wind
- Surface and atmosphere structure and dynamics
- Exploring the unknown

- GONG++
- SDO
- SOLIS Network
- Solar-B
- FASR
- ATST
Some Observing Capabilities in 2010

- Solar-B still operational
- ATST
  - Fully operational delivering 0.05 arcsec resolution over 10 arcsec
  - Covers the 300 nm to 30 µm wavelength range
  - To be upgraded with MCAO delivering 0.05 arcsec over 100 arcsec
- SOLIS Network: Provides full-disk vector-magnetograms every few hours 24 hours a day
- Solar Dynamics Observatory: Provides full-disk synoptic data including vector-magnetograms with 1 arcsec resolution
- Solar Orbiter to be launched within 2 years
- These facilities can address a large part of the science goals mentioned above
Photon Starvation at the Diffraction Limit

- Unobscured aperture
- 10% overall efficiency (including detectors)
- Maximum horizontal motion of 5 km/s
- Solar image is not allowed to evolve more than half a pixel
- Spectral resolution of 150,000
- Nyquist sampled in space (diffraction-limited) and spectrum
- Look at a single spatial and spectral pixel
For a 4-m telescope, diffraction-limited data can only be integrated during about 1 second!

![Graph showing the relationship between effective diameter, time, and wavelength.](Image)
Maximum SNR at Diffraction Limit

**Instruments and Observations**

<table>
<thead>
<tr>
<th>effective diameter [m]</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>630 nm</td>
</tr>
<tr>
<td></td>
<td>1548 nm</td>
</tr>
<tr>
<td></td>
<td>300 nm</td>
</tr>
</tbody>
</table>
High-resolution spectro-polarimetry is photon-starved

- The bigger the telescope, the smaller the maximum achievable SNR at the diffraction limit
- Photon flux rather than diffraction determines aperture size
- Interferometers will only provide very limited spectral resolution
- By 2010, it is unlikely to gain much in science capabilities from visible-light telescope in space
Advantages of Space

- Thanks to Ted Tarbell
- 24 hours of sunshine and good weather every day
- Perfect seeing over very large field of view
- Excellent uniformity of observing conditions
- Visible, UV, EUV, X-ray, IR instruments on the same platform
April 5, 2001

Beyond Solar-B Workshop Summary:
Instruments and Observations

Spatial vs Wavelength Coverage

New Mission Opportunity

Wavelength

Gamma-ray  X-ray  EUV  UV  Visible  Near-IR  Thermal IR  Radio

0.02"
0.2"
2"
20"
200"
2000"

Space

SDO  SOLIS  Solar-B  HESSI  ATST  FASR
High-Resolution Coverage of Atmosphere

- photosphere
- chromosphere
- transition region
- corona

ATST

New Mission Opportunity

April 5, 2001
Beyond Solar-B Workshop Summary: Instruments and Observations
Advanced Solar Space Telescope: Science

- Overall science goal:
  *Understand the dynamic coupling of the magnetized solar atmosphere from the photosphere to the corona*

- Primary mission:
  *Provide very high-resolution observations of those parts of the solar atmosphere that cannot be easily observed from the ground (upper chromosphere, transition region, corona on the disk)*

- Secondary mission:
  *Provide simultaneous high-resolution observations that can easily be correlated with ground-based data*
Advanced Solar Space Telescope

- “avoid trying to come up with the instrument”
- 2-m class space telescope giving access to visible, UV, EUV, soft X-ray
- Research facility with high flexibility: spectrographs and filter-based instrument that can do polarimetry
- Combine with other Roadmap missions (?)
- "complicated thing full of optics, the kind of thing that Lockheed likes to build“
Thanks To

- Ron Moore
- John Davis
- David Hathaway
- Pat Corder
- Diane Nelms